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# Cancer Mortality in Women With Probable Exposure to Silica: A Death Certificate Study in 24 States of the U.S.

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**Background:** *Silica exposure is known to cause an increased risk of pneumoconiosis and some types of cancers. Exposure to silica is becoming an increasingly common occupational hazard for women. Studies contradict each other on whether or not women suffer more occupational pneumoconiosis than men, but no studies have evaluated cancer risks among women exposed to silica.*
**Methods:** *Death certificate data on occupation and industry from 24 states in the U.S. between 1984 and 1993 were used to calculate proportional mortality ratios (PMRs) for workers exposed to silica.*
**Results:** *Over 20,000 deaths (4% of all deaths in persons with possible work-related silica-exposure) occurred among women. The PMR for pneumoconiosis among women working in occupations or industries with possible silica exposure was 13.6 (95% CI: 7.2–23.2), for men 3.8 (CI: 3.7–4.0). Both men and women had higher than expected PMRs for respiratory diseases, lung and esophageal cancers, and external causes of death. In the group with probable silica exposure (both occupation and industry associated with silica), women had elevated PMRs for thyroid cancer (PMR = 5.5), multiple myeloma (PMR = 1.3), digestive organ cancers (PMR = 1.2), whereas men had no increased PMRs for these cancers. Both genders had significantly decreased PMRs for breast cancer, cerebrovascular diseases, nervous system diseases, and brain and other central nervous system cancers.*
**Conclusions:** *An in depth look at the types of silica exposures (specific work duties) and adjustment for confounders is warranted to determine the importance of these gender-specific excess mortalities associated with possible silica exposure.* Am. J. Ind. Med. 36:122–128, 1999. *Published 1999 Wiley-Liss, Inc.*†

***KEY WORDS: women; silica; occupational exposure; cancer; PMRs; pneumoconiosis***

## INTRODUCTION

The numbers of women working in high-silica exposure occupations and industries are increasing. For example, between 1970 and 1990 the number of women working in the mining industry doubled, and in the construction industry tripled [US Department of Commerce, 1980, 1990]. Silica exposures are high in mining, construction, grinding/polishing machine operators, and drilling, which are relatively new jobs for women. The glass and pottery industries, which have a longer history of employing women, also typically involve exposure to silica. Despite numerous articles on the association of cancer or respiratory diseases with silica exposure, few studies have looked at the effect of silica exposure on women. Some studies had women subjects but did not report their mortality and cancer incidence separately from that of men [Aungkasuvapala et al., 1995; Dong et al., 1995]. In other studies, the small

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number of women precluded meaningful analyses by gender [Rafnsson and Gunnarsdottir, 1997; Andjelkovich et al., 1992].

In silica-exposed populations, studies are available on gender differences of pneumoconiosis but not of mortality. Of the studies which report incidence rates for silicosis in both men and women, one suggests that women may be more susceptible than men to pneumoconiosis, as they tend to be diagnosed with pneumoconiosis after fewer years of work exposure [Zitting et al., 1996]. However, three studies show no significant gender differences in incidence rates of pneumoconiosis [Gerhardsson and Ahlmark, 1985; Rastogi et al., 1991; Gielec et al., 1992].

Increased risk of tuberculosis has long been associated with inhaled silica dusts. In two studies with data on both genders, one found an excess of tuberculosis among women compared to men in the pottery industry [Ahlmark et al., 1960], but the other study found the incidence of tuberculosis to be similar among men and women [Gerhardsson and Ahlmark, 1985].

This study utilizes a dataset of mortality records collected from 24 states over a 9-year period (1984–1993). In these data, the number of exposed women was much larger than previously published studies of silica exposure and women, making it possible to find statistically significant proportional mortality ratios (PMRs) for at least some causes of death. The purpose of this study was to analyze PMRs of women exposed to silica and make relative comparisons to the PMRs of men with similar exposures.

## MATERIALS AND METHODS

Through a collaborative effort, the National Cancer Institute, the National Institute for Occupational Safety and Health (NIOSH), and the National Center for Health Statistics supported the coding of ''usual'' occupation and industry listed on death certificates from 24 states (Colorado, Georgia, Idaho, Indiana, Kansas, Kentucky, Maine, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, North Carolina, Ohio, Oklahoma, Rhode Island, South Carolina, Tennessee, Utah, Washington, West Virginia, Wisconsin, Vermont). This dataset contains more than 5 million deaths from 1984–1993. The occupation and industry three-digit codings correspond with US Department of Commerce Census code headings and job descriptions [US Department of Commerce, 1980]. Table I lists the codes which were classified as occupations and industries with possible high-silica exposure for this analysis. These occupations and industries were chosen by the industrial hygienist on the team as having the highest chance of significant silica exposures.

PMRs were used to evaluate mortality risks of individuals working in occupations and/or industries with probable exposure to silica [Monson, 1990]. Significance was determined by the chi-square test, and confidence intervals (95% CI) were calculated according to Liddell [1984].

**TABLE I.** Department of Commerce Census Codes for Occupations and Industries With High Exposures to Silica

| Occupational codes | |
|---|---|
| 553 | Supervisors: brick masons, stonemasons, and tile setters |
| 563 | Brickmasons and stonemasons |
| 564 | Brickmason and stonemason apprentices |
| 588 | Concrete and terrazzo finishers |
| 589 | Glaziers |
| 595 | Roofers |
| 598 | Drillers of earth |
| 599 | Construction trades, n.e.c.* |
| 613 | Supervisors, extractive occupations |
| 615 | Explosive workers |
| 616 | Mining machine operators |
| 617 | Mining occupations, n.e.c. |
| 709 | Machine operators: grinding abrading, buffing and polishing machine |
| 768 | Crushing and grinding machine operators |
| 853 | Excavating and loading machine operators |
| 855 | Grader, dozer, and scraper operators |
| 865 | Helpers, construction trades |
| 867 | Helpers, extractive occupation |
| 869 | Construction laborers |
| **Industrial codes** | |
| 040 | Metal mining |
| 041 | Coal mining |
| 050 | Nonmetallic mining and quarrying, except fuel |
| 060 | Construction |
| 250 | Glass and glass products |
| 251 | Cement, concrete, gypsum, and plaster products |
| 252 | Structural clay products |
| 261 | Pottery and related products |
| 262 | Miscellaneous, nonmetallic mineral and stone products |
| 270 | Blast furnaces, steelworkers, rolling and finishing mills |
| 271 | Iron and steel foundries |
| 272 | Aluminum industries |
| 280 | Other primary metal industries |

*n.e.c. = not elsewhere classified.

This article evaluates PMRs for two groups of decedents. The largest group is composed of those who work in either an occupation *or* an industry with a *possible* exposure to silica (identified as those persons working in occupations *or* industries listed in Table I). The smaller of the two groups includes those persons who work in occupations which are likely to have silica exposure and industries in which everyone with these occupations are *probably* exposed to

silica (persons whose occupations *and* industries are listed in Table I).

The causes of death listed in the tables were chosen if they were associated with silica exposures in other studies, or if PMRs among the probably-exposed women are significantly increased or decreased. ICD-9 diagnosis definitions were used. For example, ''external causes of death'' includes all ''E'' coded ICD-9 numbers; pneumoconiosis includes that from all causes (ICD-9: 500–505.9). [WHO, 1977]

## RESULTS

Among the more than one-half million decedents whose usual occupations or industries may have silica exposure, only 4% (20,688) were deaths of women (Table II). Ninety-six percent of the women and 73% of the men who were identified as working in jobs with possible silica exposure were identified by industry alone; 915 women had both occupations and industries associated with silica exposures.

Table III presents PMRs for selected causes of death among women and men working in an occupation *or* industry with possible silica exposure. The relative risk of these women dying from ''all malignant neoplasms'' was 6% greater than women in all occupations and industries. Men in these jobs did not have a significantly increased PMR for all cancers.

The PMRs for respiratory system cancer, the majority of which was lung cancer, were significantly elevated: 12% among men and 19% among women (Table III). Multiple myeloma PMRs were significantly increased among women (PMR = 1.3), but not among men (PMR = 0.9). PMRs for digestive organ cancers were approximately the same as expected for women, but PMRs for men were lower than expected. Esophageal cancer PMRs were mildly elevated for both sexes.

Possible silica in the workplace was associated with increased mortality for respiratory disease among both women (PMR = 1.1; 95% CI: 1.0–1.1) and men (PMR = 1.1; 95% CI: 1.1–1.1). Women with possible exposure to silica had a PMR for pneumoconiosis of 13.6 (95% CI: 7.2–23.2), significantly higher than expected. The PMR for pneumoconiosis among men was 3.8 (95% CI: 3.7–4.0). The PMR for tuberculosis was elevated among men (PMR = 1.2; 95% CI: 1.1–1.3), but not among women (PMR = 0.6; 95% CI: 0.3–1.2). The PMRs for deaths from external causes were 20% higher than expected for women and 14% higher than expected for men.

Table III shows some mild decreases in PMRs for nervous system diseases (PMRs women: 0.86 and men: 0.81) and cerebrovascular diseases (PMRs 0.93 and 0.97) among both sexes, as well as for brain and other central nervous system (CNS) cancers among men (PMR 0.8; 95% CI: 0.8–0.8).

**TABLE II.** Numbers of Deaths of Persons Whose Primary Occupation and/or Primary Industry Listed on Their Death Certificates was Classified as a High Silica Exposure

| | Number of deaths | |
|---|---|---|
| **Data listing** | **Women** | **Men** |
| Occupation | 1,503 | 147,146 |
| Industry | 20,100 | 480,325 |
| Occupation or industry silica exposure categorized as possible | 20,688 | 494,366 |
| Both occupation and industry silica exposure categorized as probable | 915 | 133,105 |

Study in 24 states 1984–1993.

Table IV presents PMRs for individuals whose death certificate reported occupations *and* industries which probably have silica exposure. PMRs for all cancers combined were lower than those in Table III, 0.97 for men and 0.89 for women. Respiratory cancers, all digestive organ cancers, lymphatic/hematopoietic cancers, multiple myeloma, and cerebrovascular diseases tended to have approximately the same PMRs as in Table III, though the PMRs for women showed less statistical significance because of the smaller numbers. Both women and men tended to have increased esophageal cancer PMRs (PMR = 2.7; 95% CI: 1.0–5.8 and 1.1, 95% CI: 1.0–1.2, respectively). Thyroid cancer PMRs were significantly elevated among women (PMR = 5.51; 95% CI: 1.11–16.11) but not among men (PMR = 0.93; 95% CI: 0.66–1.28). Although the PMR for the probably-exposed group was statistically significant, this was determined by just three cases in a population which ordinarily would not be expected to have any (expected number of cases: 0.5).

The PMR for breast cancer was significantly decreased for women (PMR = 0.6; 95% CI: 0.4–0.9) in Table IV. PMRs for brain and other CNS cancers significantly decreased among both genders in this more specific exposed group. PMR decreases in nervous system diseases (PMR = 0.5 and 0.7) were also significant for both genders in this subpopulation.

Both women (PMR = 1.2) and men (PMR = 1.3) tend to have an increased relative risk of respiratory diseases in this subpopulation of workers with probable exposure to silica. The large PMR for pneumoconiosis among women (54.1) was based on only two deaths, while among men the PMR (11.6) was based on a much larger number. No deaths due to tuberculosis were identified among women. Men had significantly increased tuberculosis mortality (PMR = 1.6; 95% CI: 1.4–1.8).

PMRs for external causes of death were even more significantly elevated for women (1.6) and men (1.2) in

**TABLE III.** PMRs for Selected Causes of Death Among Women and Men Working in Occupations or Industries With Possible Silica Exposure and Number of Deaths for Persons With These Jobs

| | Women | | Men | |
|---|---|---|---|---|
| **Cause of death** | **PMR (C.I.)** | **No. deaths** | **PMR (C.I.)** | **No. deaths** |
| All malignant neoplasms | 1.06 (1.03–1.09) | 14907 | 1.01 (1.00–1.02) | 123758 |
| Brain & other CNS cancers | 0.99 (0.83–1.17) | 134 | 0.81 (0.77–0.84) | 2294 |
| Respiratory system cancers | 1.19 (1.13–1.26) | 1441 | 1.12 (1.11–1.13) | 50813 |
| Digestive organ cancers* | 1.02 (0.97–1.08) | 1222 | 0.95 (0.95–0.96) | 26697 |
| Esophageal cancers | 1.21 (0.92–1.57) | 59 | 1.05 (1.02–1.09) | 3488 |
| Lymphatic/hematopoetic ca | 1.03 (0.94–1.12) | 535 | 0.88 (0.86–0.90) | 10099 |
| Multiple myeloma | 1.29 (1.07–1.54) | 122 | 0.89 (0.85–0.93) | 1833 |
| Thyroid cancers | 1.29 (0.75–2.07) | 17 | 0.89 (0.75–1.04) | 149 |
| Breast cancers | 1.00 (0.94–1.06) | 1050 | 0.67 (0.54–0.83) | 88 |
| Nervous system diseases | 0.86 (0.78–0.95) | 375 | 0.81 (0.79–0.82) | 6548 |
| Cerebrovascular diseases | 0.93 (0.89–0.98) | 1584 | 0.97 (0.96–0.98) | 26162 |
| Respiratory diseases** | 1.07 (1.02–1.12) | 1871 | 1.12 (1.11–1.13) | 50284 |
| Pneumoconioses | 13.59 (7.23–23.24) | 13 | 3.84 (3.68–4.00) | 2163 |
| Tuberculosis | 0.60 (0.26–1.19) | 6 | 1.17 (1.07–1.27) | 544 |
| External causes of death | 1.20 (1.13–1.27) | 1222 | 1.14 (1.13–1.15) | 50338 |
| All causes of death | | 20688 | | 494366 |

C.I. = 95% confidence interval.
ca = cancers.
CNS = central nervous system.
*Also includes peritoneal cancers.
**Includes asthma, emphysema, pneumonia, tuberculosis, and pneumoconiosis.
24 states, 1984–1993.

Table IV than in the less-specific Table III. Virtually all components of ''external causes of death'' (not shown in tables): motor vehicle accidents, homicide, falls, suicide, accidental poisoning, intentional or unintentional firearms, and other (nontransport) unintentional trauma had elevated PMRs regardless of gender.

## DISCUSSION

The analysis of death certificate data from persons whose usual employment was in jobs with possible or probable exposure to silica found PMRs highest for women's deaths from pneumoconiosis (14–54-fold above expected). Men in these same jobs also had high PMRs (4–12-fold above expected). Tuberculosis PMRs had a 60% increase among men, but no increase among women. Respiratory disease PMRs were as much as 25–33% more than expected for both sexes; increases in PMRs for respiratory system cancers were about half this amount. PMRs for digestive organ, esophageal and thyroid cancers, multiple myeloma, and external causes of death were consistently elevated among women, more so than among men.

The current literature suggests no explanations for why PMRs for silica exposures were associated with significantly decreased deaths from nervous system and cerebrovascular diseases, breast cancer, and brain and other CNS cancers for both genders.

The majority of *possibly* exposed women and men were classified as such solely on the basis of industry of employment. Employment in these industries could be anything from a plant worker to an executive, all receiving quite different exposures to silica. More women than men hold clerical jobs and were thus more likely to be misclassified as exposed. Men and women with *probable* exposure to silica at the workplace leaves out persons, such as factory floor custodial workers, who may have very high silica exposure in these industries. Nonetheless, since pneumoconiosis is considered pathognomonic for silica exposure and the probably-exposed group has much higher PMRs for this disease, we succeeded in creating a group which is more specific for silica exposure than the possibly-exposed group.

We use the term ''relative'' when comparing PMRs by gender in order to keep in mind two caveats. First, the

**TABLE IV.** PMRs for Selected Causes of Deaths Among Women and Men With Probable Silica Exposures Based on Occupations Within Specific Industries Associated With Silica Exposure and Number of Deaths for Persons With These Jobs

| | Women | | Men | |
|---|---|---|---|---|
| **Cause of death** | **PMR (C.I.)** | **No. deaths** | **PMR (C.I.)** | **No deaths** |
| All malignant neoplasms | 0.89 (0.78–1.02) | 208 | 0.97 (0.96–0.98) | 30837 |
| Brain & other CNS cancers | 0.15 (0.00–0.81) | 1 | 0.60 (0.55–0.66) | 427 |
| Respiratory system cancers | 1.11 (0.82–1.46) | 49 | 1.15 (1.13–1.17) | 13304 |
| Digestive organ cancers* | 1.15 (0.87–1.50) | 54 | 0.87 (0.85–0.90) | 6459 |
| Esophageal cancers | 2.66 (0.97–5.79) | 6 | 1.08 (1.02–1.15) | 1028 |
| Lymphatic/hematopoetic ca | 0.86 (0.53–1.33) | 20 | 0.76 (0.73–0.80) | 2268 |
| Multiple myeloma | 1.33 (0.43–3.59) | 5 | 0.78 (0.71–0.86) | 433 |
| Thyroid cancers | 5.51 (1.11–16.11) | 3 | 0.93 (0.66–1.28) | 39 |
| Breast cancers | 0.64 (0.43–0.90) | 32 | 0.79 (0.52–1.15) | 27 |
| Nervous system diseases | 0.54 (0.26–0.99) | 10 | 0.70 (0.67–0.74) | 1479 |
| Cerebrovascular diseases | 0.75 (0.55–0.99) | 49 | 0.93 (0.91–0.95) | 6785 |
| Respiratory diseases** | 1.25 (0.99–1.56) | 78 | 1.33 (1.30–1.35) | 14985 |
| Pneumoconioses | 54.1 (6.1–195.2) | 2 | 11.6 (11.0–12.2) | 1578 |
| Tuberculosis | 0 (0–4.18) | 0 | 1.59 (1.40–1.80) | 241 |
| External causes of death | 1.65 (1.41–1.91) | 175 | 1.18 (1.16–1.20) | 17432 |
| All causes of death | | 915 | | 133105 |

C.I. = 95% confidence interval.
ca = cancers.
CNS = central nervous system.
*Also includes peritoneal cancers.
**Includes asthma, emphysema, pneumonia, tuberculosis, and pneumoconiosis.
24 states, 1984–1993.

exposed women's PMRs are relative to all women, and PMRs for exposed men are relative to all men. In the majority of the causes of death discussed in this article, men have higher mortality rates than women in the general population, with the exception of nervous system diseases, thyroid cancers, and breast cancers [CDC, 1998]. Many of the women's PMRs are relatively higher than men, although the actual mortality rates would not be higher. For example, in the case of pneumoconiosis, the total population mortality rate for men is many times higher than for women. Despite a PMR of 4 among men and a PMR of 14 among women, men may still have a higher mortality rate for pneumoconiosis than women in these jobs.

Second, the cohort of women is younger than men in these relatively ''new'' jobs for women (which may also suggest shorter exposure durations), and the PMRs are not adjusted for age distribution differences between genders.

Although a few studies compare respiratory diseases and silica exposure by gender, to date no published studies compare mortality data for both men and women exposed to silica. The literature is unclear as to whether or not pneumoconiotic disease incidence among silica-exposed women is higher than among men [Rastogi et al., 1991; Gerhardsson and Ahlmark, 1985; Zitting et al., 1996; Gielec et al., 1992]. However, two studies found women diagnosed with pneumoconiosis after fewer years of occupational exposure than men [Gerhardsson and Ahlmark, 1985; Bruce, 1942]. Our study found very high pneumoconiosis PMRs which were relatively higher among women than men.

Our study confirms the literature which finds silica exposure associated with higher relative risk of mortality from pulmonary infections [Hobbesland et al., 1997; Mehnert et al., 1990]. Two studies on male and female rates of tuberculosis are contradictory as to which gender had a higher risk when exposed to silica [Ahlmark et al., 1960; Gerhardsson and Ahlmark, 1985], but our study clearly showed a significantly increased PMRs among men and no increase among women. This gender difference needs to be qualified, since by the time women began to work in these jobs tuberculosis had become a rare disease.

No published study has evaluated the association of deaths from external causes and silica exposures. This study showed an increased relative risk for both genders which was even greater in the more specific group. This finding

may reflect a greater risk of on-the-job injury and lower socioeconomic status (and increased lifestyle risks) of the probably-exposed group.

The increased PMRs for lung cancer agrees with most published studies [IARC, 1997; Meijers et al., 1996; Partanen et al., 1995; Hnizdo et al., 1997; Steenland and Stayner, 1997], although rates tended to be only slightly elevated. Socioeconomic status and smoking (see below) may be factors influencing part of this PMR elevation.

The association of silica exposure with digestive system cancers in the literature is not consistent [IARC, 1997; Neuberger and Kundi, 1990; Amandus et al., 1995; Rafnsson and Gunnarsdottir, 1997; Chen et al., 1992]. In this study, women with possible and probable silica exposure had elevated PMRs for all digestive cancers, but men did not. Both genders had an increased PMR for esophageal cancer, but few previous studies have looked specifically at this cancer and silica exposure [IARC, 1997], although one study found a nonsignificant association [Chen et al., 1992]. Other studies have found increased risk of esophageal cancer (without specifying women) among vulcanization workers [Norell et al., 1983], combustion workers [Gustavsson et al., 1993], metal workers, and farmers with significant alcohol intakes [Ronco, 1992]. The most common esophageal cancer is squamous cell and it is associated with low socioeconomic status, alcohol, and smoking [Day, 1975].

The increased PMR for multiple myeloma among possibly and probably silica-exposed women and the decreased PMR among men in this study has not been previously noted in the literature [IARC, 1997]. Higher mortality rates, PMRs, or relative risks in women than men for multiple myeloma have been seen in farmers [Zahm, 1992; Khuder and Mutgi, 1997], sheet metal workers [Fritschi and Siemiatycki, 1996], and aircraft maintenance workers [Blair et al., 1998].

Thyroid cancer PMRs were significantly elevated among women, but not men. Thyroid cancer is more common among women than men in the general population [NCI, 1997], and no association is known between thyroid cancer and socioeconomic status or smoking [Ron, 1997]. Although an increase in thyroid cancer risk exists among workers exposed to radiation, this increase in not evident for radon exposure to which miners and quarriers may be subjected [Ron, 1997]. No other job exposures are known to be associated with thyroid cancer.

Significant decreases in PMRs for nervous system diseases, breast cancer, brain and other CNS cancers partly reflect that persons in these occupations and industries tend to have lower socioeconomic status than the general population [Stalsberg et al., 1989; Demers et al., 1991]. Decreased cerebrovascular PMRs, however, would not be expected among lower socioeconomic groups [Vågerö and Norell, 1989]. Since a protective association between silica and brain and neurologic diseases has not been mentioned elsewhere in the literature [IARC, 1997], the decreased PMRs in this study needs to be evaluated in other studies.

This study was limited to information from death certificates, which give no information on confounders other than gender and age. For example, besides the unaccounted-for socioeconomic status confounder mentioned previously, no information was available on confounders such as alcohol or smoking use (which could affect our findings for lung, esophageal, and some other digestive cancers). Data on cigarette smoking by occupation indicate that persons in these occupations tend to have higher current smoking rates than the same age general population [Brackbill et al., 1988]. In addition to the problems of misclassification of individuals as silica exposed because of inadequate exposure information on death certificates discussed earlier, exposure duration and specific type of exposure cannot be evaluated. One study noted that in pottery shops Swedish women tended to work as finishers of fired wares, and thus generally have more silica exposure than men working in the same shop [Gerhardsson and Ahlmark, 1985].

Despite the limitations of death certificate information, this study gives an overview of deaths associated with silica in women, which previously has not been done. Further studies which shed light on confounders and adjust for risk factors will help to determine if silica jobs present an increased risk for women, and if a decreased risk really is associated with certain diseases and silica exposure.

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